A. PROJECT GOALS AND SCOPE OF WORK

1. Description of the problem to be addressed

The Sacramento perch (SP,*Archoplites interruptus*) is a native sunfish that once was abundant, but is now extirpated from almost all of its former habitats throughout the Sacramento- San Joaquin watershed (Tharratt and McKechnie 1966, Aceituno and Nicola 1976, Leidy 1984, Gobalet and Jones 1995, Moyle 2002). In the 19th century it was abundant enough in the San Francisco Estuary to support a commercial fishery (Moyle 2002). SP have been listed as a species targeted for recovery in the Delta Native fishes Recovery Plan (Moyle et al. 1995), are listed by the Department of Fish and Game as a species of special concern (Moyle 1995), and are classified by CALFED as an At-Risk (Priority Group 2) species in the 2001 ERP (Goal 1, objective 2, pp.140). SP would undoubtedly be listed as an endangered species if there were not so many populations established outside its native range. Only two native populations seem to be maintaining themselves, if tenuously: in Clear Lake and in the Alameda Creek drainage.

Of the introduced populations, the ones in the upper Klamath watershed, in Pyramid Lake, Nevada, in the lower Walker River, and the ones in the Owens River are probably reasonably secure because of their abundance and fairly broad distribution within these waters. However, the history of most populations established outside their native range suggests that long-term persistence is problematical (P. Crain, unpublished data). Extirpations of introduced populations are usually the result of changing conditions in managed waters, but precise causes are often not known. Although some life history information for California populations is available (e.g., Aceituno and Vanicek 1976, summarized in Moyle, 2002), little is known about its physiological tolerance limits and behavioral tendencies. Although SP have a reputation for being physiologically very tolerant (i.e., capable of living in water in which most freshwater fishes cannot persist) physical/chemical environmental factors may be limiting their distribution and abundance, especially at early life history stages. The juvenile and adult SP's physiological and behavioral responses to factors such as water temperature, salinity, pH, dissolved oxygen, and velocity need to be quantitatively defined.

Recovery strategies for SP in the San Francisco Estuary have been proposed for study (Moyle et al. 1995), but have not been developed because the general lack of biological knowledge necessary for developing recovery strategies. While generally considered to have declined because of interactions with alien fishes (Aceituno and Nicola 1976, Marchetti 2000), opportunities for recovery may still exist if the proper strategies are used. Introduction into areas without potential competitors and predators (e.g., Suisun Marsh) might allow SP to establish a foothold in the San Francisco Estuary. Source populations could be developed in places like the McCormack Williamson Tract, which would then be allowed to flood, building up populations in surrounding sloughs. The interactions of these fish could be studied to see if SP could coexist with the present mix of fish in the Delta.

Goal: to develop strategies to restore SP to self-sustaining wild populations in the San Francisco Estuary, and to assure the SP long-term future in Central California.

Research Question 1: What information exists that could help in developing strategies for restoration of the SP? Is information that comes from translocated populations outside of the SP original range pertinent to the San Francisco Estuary?

Objective 1: summarize existing information on SP, emphasizing factors contributing to survival of introduced populations, collapse of native populations, and persistence of some native populations.

Hypothesis 1a: Ecological, Physical, and chemical conditions in the San Francisco Estuary are still within the range of conditions used by Sacramento perch in translocated populations.

Research Question 2: What are the early life history requirements of SP? What are the factors that lead to the survival of SP larvae and juveniles? Because there have been no studies of early life history it is not known whether early life history is a bottleneck to SP recovery.

Objective 2: document early life history of SP and the factors contributing to survival of early life history stages.

Hypothesis2a: SP populations are limited by mortality in first 1-2 months of life.

Research Question 3: What are the basic environmental requirements of Sacramento perch? What are its physiological tolerance limits and its behavioral attributes? The basic environmental tolerances of SP are poorly defined, although SP have a reputation for being physiologically very tolerant, capable of living in water in which other centrarchids cannot persist. These limits and tendencies need to be better defined in order to determine what factors (i.e., water temperature, salinity, pH, dissolved oxygen, and velocity) may be limiting the distribution and abundance of both juvenile and adult SP.

Objective 3: Document physiological tolerance limits and preferences of juvenile and adult SP, specifically regarding upper and lower temperature limits, upper salinity limits, upper and lower pH limits, lower dissolved oxygen limits, and upper velocity limits.

Hypothesis 3a: SP are not limited by present conditions in SF Estuary.

Hypothesis 3b: SP are physiologically capable of living and reproducing in parts of estuary that may be too saline for potential competitors, especially other centrarchids (e.g., Suisun Marsh).

Hypothesis 3c: Re-established SP populations may be limited by hydrological factors, such as transport to undesirable habitats or entrainment.

Research Question 4: What is the distribution of genetic variation within and among the extant populations of the Sacramento perch (SP, *Archoplites interruptus*)? Nothing is known about the current status of genetic variation within and among the remaining indigenous and transplanted populations of SP. It is suspected, but not known, that nearly all transplanted populations came from a single source, a small artificial floodplain lake (Brickyard Pond) in Sacramento. Only two native populations are known to exist, (Alameda Creek and Clear Lake) but their genetic relationship to transplanted populations is not known. The Clear Lake population is of particular interest because it appears to be able to coexist with a wide variety of non-native centrarchids. Without the knowledge of which populations (especially those transplanted) remain genetically diverse, we cannot make good decisions about the source of fish for restoration activities.

Objective 4: Document the genetic variation within and among the extant populations of SP by examining variation at microsatellite loci.

Hypothesis 4a: Large amounts of genetic variation exist within and among the current indigenous and transplanted populations of SP.

Hypothesis 4b: Transplanted populations have passed through a genetic bottleneck, so have limited usefulness for restoration.

Hypothesis 4c. There were several different source populations for the current transplanted populations.

Objective 5: Develop re-establishment strategies for SP, including analysis of institutional, physical, and biological barriers to their reintroduction into the San Francisco Estuary and Central Valley.

Hypothesis 5a. With adequate knowledge, Sacramento perch can be re-established in San Francisco Estuary and other locations in the Central Valley.

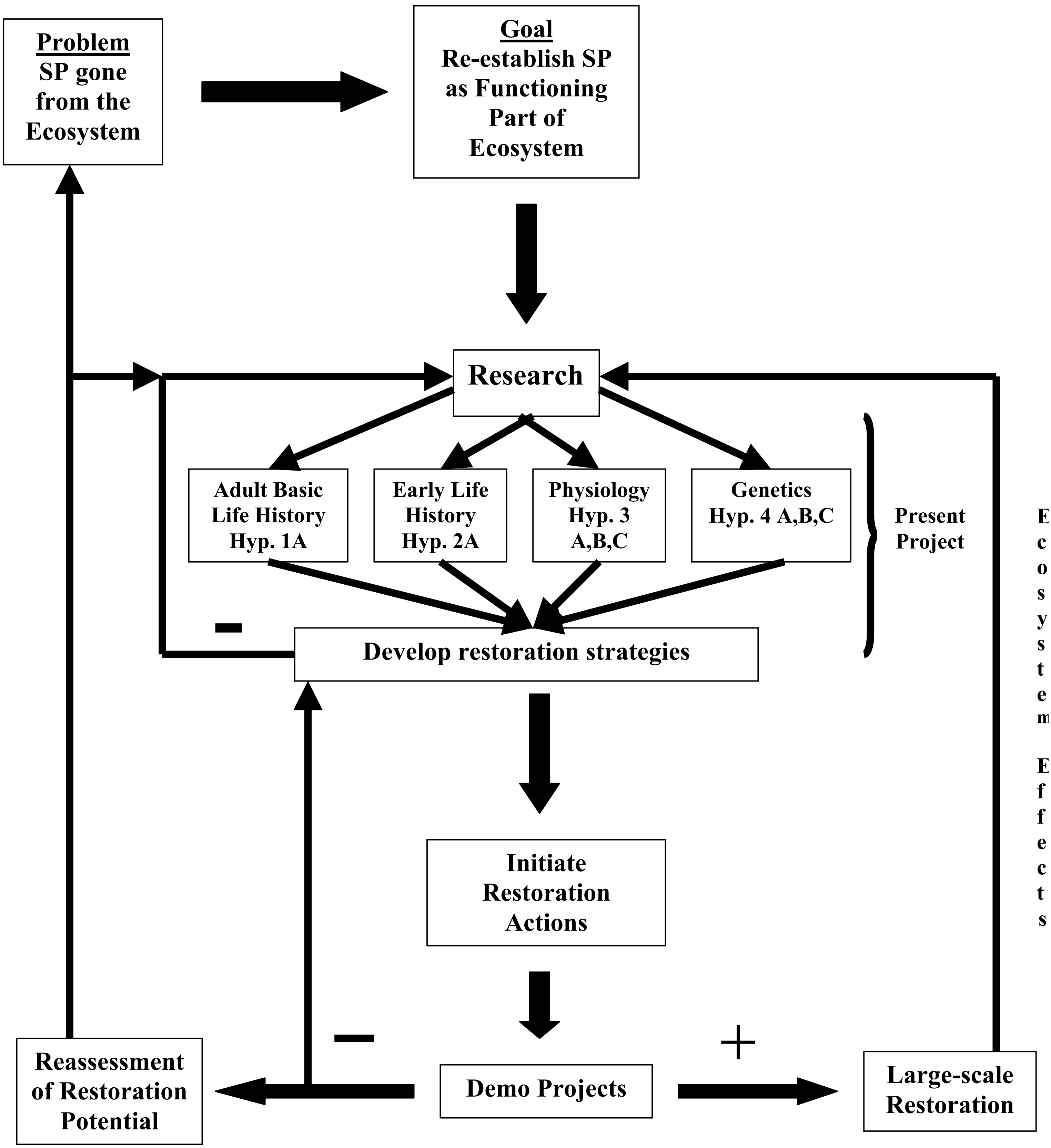
2. Justification

This project on SP is focused on the ecology, physiology, and genetics of the SP of which very little is known. What we learn from this research will be the building blocks of the recovery plan for the SP.

Conceptual Models for Proposed Work

The present phase of this project involves basic research. As depicted in the conceptual model (Fig. 1) this is key to the planning and implementation of future restoration projects for SP. The re-establishment of Sacramento perch fits well into an adaptive management framework and is compatible with other restoration projects.

Figure 1 Conceptual Model



Hypotheses Being Tested

The four project objectives will test several hypotheses to help achieve the current CALFED Ecosystem Restoration PSP priorities (MR-1, Goal 6) for SP: ensuring the recovery of at-risk species by developing conceptual understanding and models that cross multiple regions (CALFED Ecosystem Restoration Program Plan, Draft Stage 1 Implementation Plan, pg. 41). Hypotheses letters and numbers are referenced in the conceptual model (Fig. 1).

- Hypothesis 2a: SP populations are limited by mortality in first 1-2 months of life.
- Hypothesis 3a: SP are not limited by present conditions in SF estuary. 3b. SP are physiologically capable of living in parts of estuary that may be excessively. saline for other centrarchids (e.g., Suisun Marsh).
- Hypothesis 3c: Re-established SP populations may be limited by hydrologic conditions (e.g., entrainment).
- Hypothesis 4a: Large amounts of genetic variation exist within and among the current indigenous and transplanted populations of SP.
- 4b. Some transplanted populations of SP have retained more genetic variation than others.
- Hypothesis 4c: There were several different source populations for the current transplanted populations. The over-riding hypothesis is that with adequate information a successful reintroduction program for SP can be carried out.

Selection of Project Type

The proposed study is a research project, which will give information on the early life history, physiological tolerances, swimming performance, and genetics of SP. These are the building blocks needed before adaptive restoration can be attempted for the SP. The conceptual model is built around the adaptive management framework and should provide the necessary flexibility needed to restore SP successfully to the San Francisco Estuary.

3. Approach

Task 1, Summarize existing information on SP:
Although the literature is very limited on SP it will be formatted into a "white paper " containing all known information about SP known. This information will be combined with new information (Tasks 2-4) to produce a plan for reintroduction (Task 5). If information is adequate, we will develop a simple life-history model for SP that will be helpful in making management decisions.

Task 2, **Document the early life history requirements of SP:**
Early life history of Sacramento perch will be studied in Lagoon Valley Reservoir, an alkaline, public recreational lake near Vacaville that supports a large population of Sacramento perch. We will focus on factors associated with spawning timing and success (as determined by appearance of larval fish in samples) and environmental and dietary requirements of larvae and juveniles. Preliminary studies using various sampling techniques, including using light traps for larval fish and seines for juvenile fish, have demonstrated that this population is very amenable to study using techniques we have developed for studying larval and juvenile fishes in the Cosumnes River and Suisun Marsh. Light trapping will be conducted on a bi-weekly basis and seining and zooplankton tows will be done weekly at Lagoon Valley reservoir. Physical water parameters will also be monitored during each sampling. We will

also be consulting with Christopher Miller, Contra Costa MAD, who is developing artificial rearing techniques for Sacramento perch, for potential use in mosquito control.

Task 3, SP Environmental Tolerance Limits and Behavioral Tendencies: Temperature, salinity, pH, dissolved oxygen, and hydrologic conditions play important roles in the development and survival of fishes. Using juvenile and adult SP from Lagoon Valley Reservoir, tolerance limits to temperature (critical thermal maxima and minima, Becker and Genoway 1979), salinity, pH, dissolved oxygen, and water velocity (Falter and Cech, 1991,Young and Cech 1996) will be determined (loss of equilibrium endpoint). Loss of equilibrium in fish indicates physical disorganization due to the experimental variable and loss of the fish's ability to escape from conditions leading to its death (Becker and Genoway 1979). This endpoint also allows experimental recovery of these rare fish towards their eventual release at their capture site. SP water velocity limits (swimming performance as critical swimming velocities, U_{crit}) will be determined at 11, 15, and 19^{o}C using Brett-type recirculating water flumes incorporating variable-speed motors (Brett 1964, Beamish 1978, Young and Cech 1996).

A horizontal, annular environmental gradient tank (1.0 m diameter) with a telethermometer/probes/water sampling tubes array in the swimming path and a video camera/monitor system will be used for SP's (acclimated to 11, 15, or 19 C) behavioral tendencies (temperature, salinity, pH, and dissolved oxygen selection) experiments. Environmental gradients will be produced by the simultaneous introductions of water (of either different temperatures, salinities, pH, or dissolved oxygen concentrations) from plastic reservoirs into mixing chambers outside the annulus. These waters (and their mixtures) will flow towards a center drain in the apparatus, via holes and v-notches, through the annulus where the individual fish will be exposed to the resulting gradient as it swims through the annular path. This apparatus has, so far, been successfully used with steelhead (*Oncorhynchus mykiss*) and green sturgeon (*Acipenser medirostris*) exposed to temperature and salinity gradients. Hypoxic waters will be produced by counterflows of water and nitrogen gas in gas exchange columns supplying the plastic reservoirs (Cech et al. 1979), while acid or alkaline waters will be produced by HCl or NaOH additions to the reservoir waters. SP velocity preference will be determined at 19^{o}C using a flow table and video camera/monitor,recorder system that incorporates a velocity gradient. This apparatus has, so far, been successfully used with coho salmon (*Oncorhynchus kisutch*) and green sturgeon (*Acipenser medirostris*). Data will be analyzed using appropriate statistical models (e.g., ANOVA) to determine significance among treatment group means.

Task 4, Distribution of genetic variation in extant indigenous and transplanted populations of SP: Currently the best genomic markers for assessing genetic variation within and among populations are microsatellites. Microsatellite loci are noncoding regions of DNA whose alleles vary in size due to differences in the number of 2 to 5 base pair repeat units (e.g. Ca_n or $GATA_n$) that make up a locus. Only a few studies have developed microsatellite primers for Centrachidae (Colbourne et al. 1996, Neff et al. 1999, Malloy et al. 2000), and none have been shown to successfully amplify product in the genus *Archoplites*. Our experience in intergeneric cross-amplification of microsatellite primers suggests that published primers will not provide an adequate number of loci for the proposed study. Therefore, we will purchase four enriched microsatellite libraries from Genetic

Identification Services of Chatsworth, CA. Using protocols already established in our laboratory(Belfiore and May 2000, McQuown et al. 2000, Tranah et al. 2001), clones from these libraries will be grown up, sequenced on our MJ Research BaseStation, and the sequences used to design primers for a bank of microsatellite loci. These loci (markers) will be used to examine genetic variation for 40 individuals from each of approximately 12 populations, including Clear Lake, Alameda Creek, and ten transplanted populations (including Lagoon Valley Reservoir, a candidate site for sources of fish for reintroduction). Genetic variability within and among populations will be determined by scoring microsatellite variation in a number of loci. Data will be analyzed using standard genetic data analysis software and result in quantitative measures of genetic variation and divergence within and between populations including number of alleles per locus, average heterozygosities (Ho), departures from Hardy Weinberg equilibrium, inbreeding coefficients (F_{is}), estimates of gene flow (F_{st}), and genetic divergence (D). These data will be used to characterize the amount of genetic variation within each sampled population and the genetic distinctiveness among them. By combining the genetic data with the historical records of transplants we hope to identify several source populations that carry sufficient genetic variation from several different areas of the historical range of SP for use in restoration efforts on behalf of this species.

Task 5. Develop restoration strategies, assuming the information indicates reintroductions have reasonable probability of success. Among the strategies that will be evaluated are:

1. Reintroduce fish into habitats that seem to be suitable in terms of other species present and environmental conditions. We suspect that there are habitats from which Sacramento perch were extirpated decades ago that have changed enough so they may once again be suitable for them. We will develop a list of potential reintroduction sites based on personal experience, discussions with local resource managers, and limited sampling.
2. Develop populations in floodplain ponds that will become distributed into natural environments during periods of flooding. It is possible that a successful reintroduction will require a fairly large propagule size and this is one way to achieve that. This strategy would be compatible with our on-going studies of restoration of flooded habitat on the McCormick-Williamson Tract (CALFED project #99-B193) and the Cosumnes River Floodplain (CALFED Project #99-N06).
3. Develop a source-sink strategy by locating rearing ponds next to streams or sloughs that can ‘leak’ Sacramento perch on regular basis into natural habitats. We have had success in developing populations of Sacramento perch in ponds on the UC Davis campus and have observed that small numbers have wound up in Putah Creek via drainage canals.
4. Rear Sacramento perch in large numbers in ponds and other artificial situations for large-scale introduction into the wild. This is the least desirable of the options we have been considering but may be necessary if information indicates that a large propagule size is necessary for re-establishment in the wild.

4. Feasibility

This project focuses on information gathering so that reintroduction strategies can be developed. Re-establishment of Sacramento perch is likely only if we have adequate information to develop cost-effective conservation strategies. Thus this research is essential for their recovery. The work will be done by three teams of scientists headed by Moyle (ecology and life history), Cech (environmental tolerances) and May (genetics) who have well-established laboratories for the work at UC Davis and have done similar work on other species. Moyle and his research associate Patrick Crain are very knowledgeable about the biology of Sacramento perch and have widespread contacts among other biologists who have worked with them. Thus we have the background and facilities to do the basic work and a history of successful completion of similar projects, including timely publication of results. We have personnel present in our laboratories to carry out the research and have a 'pool' of workers and alternative facilities so that keeping the research going under various possible contingencies (e.g. loss of technical help, damage to a laboratory) is possible. Any one of the three Principal Investigators could take the lead in completing the project should something happen to other P.I.s.

5. Performance Measures

Quarterly reports will be submitted to CALFED with progress reports on each of the tasks as outlined.

Performance measures for summarizing existing information on SP:
- Activities: begin summary of information on SP
- Project Outputs: summary of all information into "white paper" draft

Performance measures for juvenile and larval life history study:
- Project Activities: begin light trapping and seining at Lagoon Valley Reservoir
- Begin dietary analysis of fish collected in seines
- Project Outputs: Research publication

Performance measures for SP Environmental Tolerance Limits and Behavioral Tendencies:
- determine temperature , pH, salinity, and water velocity tolerance limits and tendencies ("preferences") for juvenile and adult SP.
- Project outputs: prepare reports and manuscripts summarizing the results.

Performance measures for finding the distribution of genetic variation in extant indigenous and transplanted populations of SP:
- Develop SP specific microsatellite primers.
- Characterize genetic variation within extant and transplated populations at newly developed microsatellite loci.
- Project outputs: research publications and information on which populations to choose for repatriation.

  Performance measures for developing restoration strategies for the re-introduction of SP into the San Francisco Estuary:
  - Produce a multi-attribute list of potential reintroduction sites near or in the SF Estuary at end of study.

6. Data Handling and Storage

This is a standard series of research projects for our laboratories, so data will be handled in conventional means. Initial data is recorded on standard forms kept in notebooks. It is transferred to a spreadsheet on a PC, where it is backed up by standard means. Our intention is to publish results within a year of final data collection. Our data will be available on request after that time. We are also willing to store it in a suitable archive.

7. Expected Products and Outcomes

As active university scientists, with graduate students, staff, and postdoctoral researchers in our laboratories, we expect to be presenting results at scientific meetings and workshops as soon as we have results worth reporting. The three P.I.s have a history of working closely with agencies, disseminating quickly the information produced in our laboratories, and publishing results in a variety of places, including the IEP Newsletter. While we expect to publish results in peer-reviewed scientific journals, in the short term the key document will be the final report/white paper that will suggest conservation strategies. When completed, copies will be sent to appropriate biologists, managers, and agencies for comment and possible action, including returning to CALFED for funding of experimental restoration work.

8. Work Schedule

Task 1, Summarize existing information on SP: Begin September 2002 with completion expected by Jan 2003. Cost $3,297.00
Milestone: "white paper" done January 2003

Task 2, Document the early life history requirements of SP: Begin March 2003 with completion in August 2004. Cost $140,581.10
Milestone: peer reviewed publication on life history of SP, Presentation at regional AFS meeting April 2003.

Task 3: Start temperature, pH, salinity, and water velocity tolerance limits and tendencies ("preferences") determinations for juvenile and adult SP on 7-1-02 with completion expected by August 2004. Cost $116,336.00
Milestone 1: presentation of preliminary environmental tolerance limits and tendencies ("preferences") of juvenile and adult SP at regional AFS meeting, April 2003.
Milestone 2: presentation of environmental tolerance limits and tendencies ("preferences") of juvenile and adult SP at a national meeting, April-June 2004.
Milestone 3: completion of temperature, pH, salinity, and water velocity tolerance limits and tendencies ("preferences") determinations for juvenile and adult SP, June 2004, with report and manuscript.

Task 4: Distribution of genetic variation in extant indigenous and transplanted populations of SP: Begin September 2002 with completion expected August 2004. Cost $164,032.00
Milestone: Peer reviewed publication of SP specific microsatellite primers.
Peer reviewed publication of distribution of genetic variation in extant indigenous and transplanted populations of SP, with emphasis on preservation

of variation in some transplanted populations.

Task 5: Begin September 2002 with completion by December 2004
Milestone: Produce a multi-attribute list of potential reintroduction sites near or in the SF Estuary Task 5 is inseparable from tasks 1-4 Cost is incorporated into task 1 & 2

B. Applicability to CALFED ERP and Science Program Goals and Implementation Plan and CVPIA Priorities

1. ERP , Science Program and CVPIA Priorities.

This project specifically addresses SP a CALFED (at-risk) species (PRP Strategic goal 1, Objective 2). It will give a better understanding of the life history and habitat requirements of SP so that a self-sustaining population can once again be established in the San Francisco Estuary. It will also develop a conceptual understanding and model of processes that are essential to establish SP across multiple regions (Restoration Priorities for Multi-Regional Bay-Delta Areas No. 6, pg. 41). It will identify (task 5) suitable locations for establishing additional populations of SP in or adjacent to the San Francisco Estuary (CALFED Conditional Studies and Surveys pg. 144 ERP Draft Stage 1 Implementation Plan August 2001).

4. Previous Recipients of CALFED Program or CVPIA funding

#99-NO6 Linked Hydrogeomorphic-ecosystem Models to Support Adaptive Management: Cosumnes-Mokelumne Paired Basin Project (ERP Program)

The second quarter was spent completing the 2001 floodplain sampling schedule, initiating the laboratory analysis of samples taken during the 2001 season and planning for the 2001 watershed sampling. We: (1) completed our annual monitoring of the Cosumnes floodplain using seines, electrofishers, and fyke nets; (2) completed our annual monitoring of the river, sloughs and ditches adjacent to the Cosumnes floodplain using electroshocking; (3) continued monitoring of larval fishes in the floodplain ponds and in the rivers and sloughs adjacent to the floodplain using light traps and drift nets; (4) continued sorting and identifying larval fishes resulting from the larval sampling; (5) identified juvenile fish resulting from sub-samples taken during the 2001 sampling season; (6) continued work on a paper on factors affecting distribution of Cosumnes River fishes; (7) planned the 2001 watershed sampling and began sampling the lower river sites. Preliminary analysis of the 2001 floodplain season indicates that few native fishes utilized the floodplain during the 2001 season, likely a result of a short flooding season.
The third quarter was spent monitoring the upper and middle-lower watershed, and continued with laboratory analysis of fish samples from the floodplain during the first and second quarters. We: (1) sampled 10 watershed sites using single pass electrofishing; (2) five sites were sampled using 3 pass electrofishing; (3) took quanitative macro-invertebrate samples for stable isotope analysis; (4) took fish tissue samples in conjunction with macro-invertebrates for stable isotope analysis; (5) began micro-habitat analysis of redeye bass.
Accomplishments: presented 4 presentations at the CALFED Science conference.

#99-B193 McCormack-Williamson Tract Restoration Planning, Design and Monitoring Program I (ERP Program)

Sampling was begun in the winter quarter of 2001, we have initiated 10 permanent elecrofishing sites and 7 trawling sites around the perimeter of the McCormack-Williamson island.
The second quarter was spent initiating the fisheries monitoring within and around the perimeter of the Tract. We: (1) Established and sampled 10 permanent electrofishing sites around the perimeter of the Tract, which will be incorporated into a larger North Delta sampling regime with EBMUD and DFG;(2) Conducted a second trawl sampling around the perimeter of the tract; (3) Seined the interior pond located inside the Eastern levee. Preliminary results showed that non-native fishes dominate the habitats surrounding the Tract during late spring conditions. Planning and field scouting for a comprehensive analysis of habitat use by fish in the sloughs adjacent to the Tract was initiated.
Current Status: preliminary data for 2001 will be presented at the IEP resident fishes meeting on November 8. 2001.

#99-N02 Fish Treadmill-developed Fish Screen Criteria for Native Sacramento-San Joaquin Watershed Fishes.
Current Status: Final Technical Report will be submitted October 31, 2001

CVPIA AFSP:
Anadromous Fish Screen Program, Cooperative Agreement No. 114201J075, Aug. 2001-Oct. 2002 Fish Treadmill-developed Fish Screen Criteria for Native Sacramento-San Joaquin Watershed Fishes.
Current Status: Work began August 2001.

5. Relationship to Other Ecosystem Restoration Projects and System-wide Ecosystem Benefits

The Sacramento perch is a part of the Central California's aquatic ecosystems that has been missing for a long time. We think conditions in the estuary and elsewhere may have shifted enough so that restoring their presence is possible, especially with increased knowledge of their biology. It is likely that conditions and strategies associated with Sacramento perch restoration will also benefit other native aquatic species and could be incorporated into restoration projects in many areas, as part of the adaptive management process. Sacramento perch, as a near-extinct game fish, have some charisma and their recovery would be a significant sign of progress in the overall CALFED ecosystem restoration efforts.

C. Qualifications

JOSEPH J. CECH, JR., Ph.D., Professor of Fisheries Biology, UC Davis, 1987 to present.
Five Selected Publications: 1. Young, P.S. and J.J. Cech, Jr. 1996. Environmental tolerances and requirements of splittail. Trans. Am. Fish. Soc. 125:664-678. **2.** Crocker, C.E. and J.J. Cech, Jr. 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Env. Biol. Fish. 50:383-

389. **3.** Swanson, C., P.S. Young, and J.J. Cech, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. J. Exp. Biol. 201:333-345. **4.** Swanson, C., T. Reid, P.S. Young, and J.J. Cech, Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384-390. **5**. Myrick, C.A. and J.J. Cech, Jr. 2000. Swimming performances of four California streamfishes: temperature effects. Env. Biol. Fish. 58:289-295.

BERNIE MAY, Ph.D., Adjunct Professor, Department of Animal Science, UC Davis, 1995 to present.
Five Selected Publications: 1. Kincaid, H. L. , C.C. Krueger, and B. May. 1993. Genetic variation among remnant groups of the Green Lake strain of lake trout: preservation of the remnant Green Lake gene pool. N. Am. J. Fish. Man. 13:318-325. **2.** Perkins, D.L., J. Fitzsimons, J.E. Marsden, C.C. Krueger, and B. May. 1995. Differences in reproduction among hatchery strains of lake trout at eight spawning areas in Lake Ontario: genetic evidence from mixed-stock analysis. J. Great Lakes Res. 21:364-374. **3.** McQuown, E.C., B.L. Sloss, R.J. Sheehan, J. Rodzen, G. Tranah, and B. May. 2000. Microsatellite analysis of genetic variation in sturgeon: new primer sequences for *Scaphirynchus* and *Acipenser*. Trans. Am. Fish. Soc. 129:1380-1388. **4.** Agresti, J.J., S. Seki, A. Cnaani, S. Poompuang, E. M. Hallerman, N. Umiel, G. Hulata, G. A.E. Gall, and B. May. 2000. Breeding new strains of tilapia: development of an artificial center of origin and linkage map based on AFLP and microsatellite loci. Aquaculture. 185:43-56. **5.** Tranah, G.J., H.L. Kincaid, C.C. Krueger, D.E. Campton, B. May. 2001. Reproductive isolation in sympatric populations of pallid and shovelnose sturgeon. N. Am. J. Fish. Man. 21:367-373.

PETER B. MOYLE, PhD. Professor of Fish Biology, University of California, Davis, 1972-present.

Five selected publications. 1. Bennett, W.A., and P. B. Moyle. 1996. Where have all the fishes gone: interactive factors producing fish declines in the Sacramento-San Joaquin estuary. Pages 519-542 *in* J. T. Hollibaugh, ed. San Francisco Bay: the Ecosystem. San Francisco: AAAS, Pacific Division**. 2**. Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in California's Central Valley: an assessment. Fisheries 25(2):6-20. **3.** Marchetti, M. P. and P. B. Moyle. 2000. Spatial and temporal ecology of native and introduced fish larvae in lower Putah Creek, California. Env. Biol. Fish. 58: 75-87. **4.** Moyle, P. B., R. Pine, L. R. Brown, C. H. Hanson, B. Herbold, K. M. Lentz, L. Meng, J. J. Smith, D. A. Sweetnam, and L. Winternitz. 1996. Recovery plan for the Sacramento-San Joaquin Delta native fishes. US Fish and Wildlife Service, Portland, Oregon. 193 pp. **5.** Moyle, P. B. 2001. Inland Fishes of California. 2nd edition. Berkeley: University of California Press (in press).

E. Local Involvement

Most of the infrastructure/equipment required for this project is already available at UC Davis. Collaboration with the city of Vacaville Department of Parks and Recreation and resource agencies will be arranged. The increased knowledge of this CALFED (at-risk) species will potentially assist many other CALFED projects.

F. Compliance with Standard Terms and Conditions

Applicants comply with State and Federal contract terms as described in Attachments D and E.

G. Literature Cited

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